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Inventor(s): Atsushi MURAKAMI
Takumi ARISAWA
Kazuo NISHIMOTO
Takahiro NIWA

Invention: SHAPE MEMORY FOAM MATERIAL

NIXON & VANDERHYE P.C.
ATTORNEYS AT LAW
1100 NORTH GLEBE ROAD
8TH FLOOR
ARLINGTON, VIRGINIA 22201-4714
(703) 816-4000
Facsimile (703) 816-4100

SPECIFICATION

SHAPE MEMORY FOAM MATERIAL

Background of the Invention

Field of the Invention

5 The present invention relates to a foam material having a shape memory property, in particular, a foam material used for fluid sealing, soundproofing, and thermal insulation, and a production method therefor. Moreover, the invention provides a soundproof cover for an automobile, comprising the shape memory foam.

10 Description of the Related Art

Various foam materials, such as a urethane foam, and liquid hardening sealing materials, such as a silicon sealant are used widely for fluid sealing, soundproofing, and thermal insulation for a joint in the buildings, the industrial appliances, and the automobiles. In order to provide the sufficient fluid sealing, soundproofing, and thermal insulation performances in these materials, the gap of a joint in the structure should be filled.

Conventional foam materials are mounted in a portion requiring a fluid sealing, soundproofing, or thermal insulation process (herein after referred to as a portion to be processed) in a compressed state such that the gap in the joint can be filled according to the thickness recovery by the elastic force of the foam material itself. However, since the conventional foam

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materials recover the thickness instantaneously when the pressure is released, the foam material or an assembly product using the foam material should be mounted in the portion to be processed while keeping the state resisting
5 to the recovery force of the foam material in the compressed state, and thus the mounting operativity is extremely poor.

Although the mounting operativity can be improved by providing a thinner foam material, since a gap is
10 generated with respect to the portion to be processed of the structure, the fluid sealing, soundproofing, and thermal insulation performances cannot be provided sufficiently. Moreover, it is also possible to reduce the recovery force of the foam material in the compressed state
15 by using a soft foam material. However, the effect thereof is slight, and rather, it leads to deterioration of the foam material strength so as to shorten the life, and in particular, deteriorate the fluid sealing performance. Accordingly, the performance of the fluid sealing,
20 soundproofing, thermal insulation, and the mounting property contradict with each other, and thus a foam material satisfying the characteristics is called for.

In contrast, as in a liquid hardening sealant material such as a silicone sealant, the gap is filled by
25 introducing a liquid substance into a gap of a portion to be processed so as to be hardened according to the chemical

reaction or the volatilization of a volatile material such as a solvent. However, the liquid hardening sealant material requires a long time in the sealing operation, and further, a long time is required for hardening of the material itself.

Moreover, JP-B-48-1903 discloses a technique for filling a gap by compressing an elastic synthetic resin sponge impregnated with a viscous resin composite, and restoring the same utilizing the hysteresis of time-restoration. However, since the foam material according to the method requires to be stored in a tightly packed state so as to retain the compressed shape so that it commences the restoration immediately after loosening the tight package even at a room temperature, in the case it is assembled in, for example, a soundproof cover, it is difficult to store in the compressed state, and thus the application range is limited.

JP-A-9-132668 discloses a shape recovery foam material comprising a closed-cell resin foam element. However, since the foam material requires a long time of several tens of days for the shape recovery, a problem arises in that the function of fluid sealing, soundproofing, thermal insulation, or the like cannot be realized immediately.

JP-B-7-39506 discloses a urethane shape memory polymer foam material, and JP-A-9-309986 discloses a shape

memory vulcanized rubber formed member with a resin blended
in a rubber. Moreover, it is known that a polynorborenene,
and a styrene butadiene copolymer provide a shape memory
polymer. By producing a sponge using these materials, a
5 foam material with a shape recovery property can be
obtained. However, in order to produce the foam material
with the shape recovery property, a hardly accessible
specific material is required, and further, a facility for
producing the foam material is necessary, and thus it is
10 not used widely.

Summary of the Invention

In view of the above-mentioned circumstances, the
invention has been achieved, and an object thereof is to
provide a foam material having the excellent performances
15 in fluid sealing, soundproofing, and thermal insulation as
well as the excellent mounting operativity to a portion to
be processed, to be obtained inexpensively without the need
of special material or facility at the time of production.
Moreover, another object of the invention is to provide a
20 production method suitable for obtaining the foam material.

Still another object of the invention is to provide a
soundproof cover for an automobile engine using the foam
material, having the excellent soundproof property.

As a result of the elaborate discussion of the
25 present inventors for solving the problems, it was found

out that a shape memory foam material with the shape retained in a compressed state without application of an external force in a room temperature, and the original thickness recovered by heating can be obtained by a
5 specific process on the foam material not requiring a special facility, that is, by cooling in the compressed state after heating and compressing, and then, releasing the pressure. Moreover, it was found out that the shape in the compressed state in a room temperature can be retained
10 further preferably by impregnating the foam material with a thermoplastic substance. It was further found out that by using such a shape memory foam material in a portion to be processed, the excellent fluid sealing, soundproofing, and thermal insulation performances can be obtained as well as
15 the mounting operation to a portion to be processed can be executed more easily. At the same time it was found out that such a shape memory foam material can provide a soundproof cover for an automobile engine with the excellent mounting property and soundproof performance.
20 The invention is based on the knowledge.

That is, in order to achieve the objects, the invention provides a shape memory foam material as a composite material produced by impregnating a base foam material in a thermoplastic substance having a melting
25 point lower than that of the base foam material, and compression, wherein the compressed state is retained in a

room temperature by a hardened product of the thermoplastic substance existing at least in the surface layer part thereof as well as the compressed state is released by softening the hardened product of the thermoplastic substance by heating. The room temperature denotes a temperature range between 18°C to 25°C.

Moreover, in order to achieve the same objects, the invention provides a production method for a shape memory foam material comprising the steps of impregnating a base foam material in a thermoplastic substance, heating and compressing the same at a temperature the same as or higher than the softening temperature of the thermoplastic resin as well as less than the softening temperature of the base foam material, cooling down while retaining the compressed state, and releasing the pressure after the cooling operation.

Furthermore, in order to achieve the same objects, the invention provides a soundproof cover for an automobile engine, comprising the shape memory foam material.

Brief Description of the Drawings

FIG. 1 is a schematic perspective view showing an embodiment of a soundproof cover for an engine (V-engine) according to the invention.

FIG. 2 is a schematic diagram for explaining the mounting state (before heating) on an engine of the

soundproof cover for an engine of FIG. 1.

FIG. 3 is a schematic diagram for explaining the mounting state (after heating) on an engine of the soundproof cover for an engine of FIG. 1.

FIG. 4 is a graph showing the results of the shape retention test of the test pieces of the embodiments.

FIG. 5 is a graph showing the results of the shape retention test of the test pieces of the embodiments.

FIG. 6 is a graph showing the results of the shape recovery test of the test pieces of the embodiments.

FIG. 7 is a graph showing the results of the shape recovery test of the test pieces of the embodiments.

Detailed Description of the Preferred Embodiments

Hereinafter, the invention will be explained in detail with reference to the drawings.

As the main component of a base foam material to be used in the invention, various kinds of polymer materials, such as a rubber, an elastomer, a thermoplastic resin, a thermosetting resin, or the like can be used. Examples of the polymer materials include natural rubbers, synthetic rubbers such as a CR (chloroprene rubber), SBR (styrene butadiene rubber), an NBR (nitrile-butadiene rubber), an EPDM (ethylene-propylene-diene terpolymer copolymer), a silicone rubber, a fluoride rubber, and an acrylic rubber, elastomers such as a soft urethane, and thermosetting

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resins such as a hard urethane, a phenolic resin, and a melamine resin, but it is not limited thereto. In the case a synthetic rubber is used, it is used as a base foam material after cross-linking. In particular, a base foam material made of a thermosetting resin or a cross-linked rubber is preferable since it has a slight rigidity change in a room temperature and at the time of heating. Moreover, since a foam material containing a soft urethane as the main component is inexpensive, and it is used widely as a cushion material so as to be easily accessible, it is particularly preferable as a base foam material. Furthermore, even in the case of a foam material made of a thermoplastic resin, it can be used as a base foam material as long as the softening temperature thereof is higher than the softening temperature of a thermoplastic substance for the impregnation therein.

Since most of the above-mentioned base foam materials including the soft urethane foam are commercially available and easily accessible as well as a special facility is not required in the production, a shape memory foam material can be obtained easily and inexpensively. In contrast, in the case of the conventional shape memory foam materials, since the foam materials should be produced from a special material and the material can hardly be accessible, the shape memory foam materials cannot be obtained easily. Moreover, a special production facility

is required for the foam materials.

Furthermore, it is preferable that a base foam material has an open-cell structure. In general, a foam material of an open cell structure has a large water absorption coefficient, a foam material of a closed-cell structure has a small water absorption coefficient, and a foam material of a mixed structure with an open cell and a closed cell has a middle water absorption coefficient. Therefore, by specifying the water absorption coefficient, the ratio of the open cell and the closed cell can be defined. The water absorption coefficient is measured according to the JIS K6767 B method. The water absorption coefficient of a base foam material used in the invention is preferably 0.2 g/cm^3 or more, more preferably 0.3 g/cm^3 or more, and further preferably 0.4 g/cm^3 or more. Moreover, the bulk density of a base foam material is preferably 100 kg/m^3 or less, more preferably 70 kg/m^3 or less, and further preferably 50 kg/m^3 or less. In the case a base foam material having the water absorption coefficient and the bulk density in these ranges is used, it can easily be impregnated with a thermoplastic substance so that a shape memory foam material with a good shape recovery property can be obtained.

As a thermoplastic substance used in the invention, various kinds of thermoplastic resins and various kinds of thermoplastic compounds can be used. However, the

thermoplastic substance should have a melting point lower than that of the base foam material, and thus it can be selected optionally according to the base foam material to be used.

5 As shown in the shape retention/shape recovery mechanism to be described later, a shape memory foam material of the invention retains its shape in a room temperature, and recovers the original shape by heating. Therefore, a thermoplastic substance having a remarkable
10 difference in an elastic modulus in a room temperature range and a high temperature range is preferable. Since the elastic modulus of a thermoplastic substance, in general, declines drastically when it reaches at the glass transition point or the melting point, also in the case of
15 a shape memory foam material according to the invention, it has the shape recovery at a temperature in the vicinity of the glass transition point or the melting point (high temperature range). Therefore, with a remarkable elastic modulus difference between both temperature ranges, the
20 shape retention/shape recovery can be carried out further preferably.

Moreover, a thermoplastic substance having the glass transition point or the melting point between a heating temperature to be used actually for the shape
25 recovery (hereinafter referred to as the execution heating temperature) and a room temperature is preferable. However,

even in the case the melting point and the glass transition point do not exist in the execution heating temperature range, since it is gradually softened by heating so as to have the shape recovery, a thermoplastic substance not having the melting point and the glass transition point in the execution heating temperature but having the softening temperature in the execution heating temperature range can also be used. In particular, it is preferable to use a thermoplastic substance having any of the glass transition point, the melting point, and the softening temperature being less than 120°C. Some of the above-mentioned base foam materials deteriorate and lose the elastic recovery force in the case they are heated at 120°C or more for the shape recovery so as not to provide the shape recovery property. Moreover, since a considerably long time is needed for heating the entirety of a shape memory foam material for the shape recovery to 120°C or more, use of a heating device with a high heating ability is required. The melting point and the glass transition point can be measured by the differential scanning calorimetry analysis (DSC). Moreover, the softening temperature can be measured by the air heating method defined in the JIS K7120.

As the substances satisfying the above conditions, for example, thermoplastic resins such as a polyethylene, a polypropylene, a polystyrene, a polyvinyl chloride, a polyvinylidene chloride, a polyvinyl acetate, a

polyacrylate, a styrene-butadiene copolymer, a chlorinated polyethylene, a polyvinylidene fluoride, an ethylene-vinyl acetate copolymer, an ethylene-vinyl acetate-vinyl chloride-acrylate copolymer, an ethylene-vinyl acetate-acrylate copolymer, an ethylene-vinyl acetate-vinyl chloride copolymer, a nylon, an acrylonitrile-butadiene copolymer, a polyacrylonitrile, a polyvinyl chloride, a polychloroprene, a polybutadiene, a thermoplastic polyimide, a polyacetal, a polyphenylene sulfide, a polycarbonate and a thermoplastic polyurethane, thermoplastic compounds such as a low melting point glass frit, a starch, a solder and a wax, can be presented. However, the substance to be used is not limited thereto.

The thermoplastic substance in the invention denotes a substance to have the elastic modulus lowered or liquefied by heating. Therefore, the acrylonitrile-butadiene copolymer, the synthetic rubber polymers such as the styrene-butadiene copolymer and the polychloroprene are, in general, cross-linked so as to be used as a cross-linked rubber. Since, in a uncross-linked state or in a low cross-linking density, they have the rigidity dramatically different in a room temperature and in a heated state, they can be used as a thermoplastic substance in the invention. Moreover, some of the thermoplastic resins start the self cross-linking by heating with a cross-linking site provided, but since they are essentially thermoplastic and they have

the rigidity dramatically different in a room temperature and in a heated state even after the self cross-linking, the self cross-linking type thermoplastic resins can also be used as a thermoplastic substance in the invention.

Moreover, a thermoplastic resin containing at least one of an acrylate, a styrene, and a vinyl acetate as a monomer unit has a glass transition point of 120°C or less, a high rigidity in a room temperature, and relatively good shape retention property and shape recovery property.

A shape memory foam material according to the invention can be obtained by impregnating the base foam material in the thermoplastic substance, heating and compressing the same at a temperature same as or higher than the softening temperature of the thermoplastic resin as well as less than the softening temperature of the base foam material, cooling down while retaining the compressed state, and releasing the pressure after the cooling operation. The shape memory foam material is a composite material wherein the compressed state is retained in a room temperature by a hardened product of the thermoplastic substance existing at least in the surface layer part thereof. The compressed state is released by softening the hardened product of the thermoplastic substance by heating.

Hereinafter, the production method will be explained in detail.

For the impregnation of the base foam material with

the thermoplastic substance, any method can be used, and a shape memory foam material can be obtained, with any method adopted. However, since a method of impregnating a base foam material with a thermoplastic substance dissolved or dispersed in a solvent, and drying the solvent, can be executed most easily, with the thermal deterioration of the foam material hardly generated, and thus it is preferable. In this case, for example, the base foam material can be impregnated with the thermoplastic substance by impregnating the base foam material in an emulsion with the thermoplastic substance dispersed or dissolved in a solvent, and drying the solvent. As the solvent, any solvent such as water, and an organic solvent can be used, but for a low toxicity at the time of drying, it is preferable to use water as the solvent. Moreover, since an emulsion with a thermoplastic resin dispersed in water is commercially available and relatively easily accessible, it is preferable as a thermoplastic substance material of a shape memory foam material of the invention. Furthermore, by optionally changing the concentration of the thermoplastic substance in the emulsion, the thermoplastic substance impregnation amount in the base foam material can be controlled.

Moreover, depending on the kind of the thermoplastic resin, it is also possible to impregnate the base foam material with a liquid monomer before

polymerization, and polymerize the monomer in the base foam material. In this case, as the monomer, it is preferable to use a styrene monomer, an acrylate monomer, a vinyl acetate monomer, a vinyl alcohol monomer, or the like.

Furthermore, it is also possible to heat and melt the thermoplastic substance, impregnate the base foam material with the liquefied product, and cooling for solidification. In this case, any thermoplastic substance can be used. However, in the case of using a foam material of a material having a low thermal resistance, such as a urethane foam and a polyethylene foam as the base foam material, it is necessary to be careful so as to prevent deterioration thereof at the time of impregnation of the thermoplastic substance.

Any method including the above-mentioned methods, can be used for impregnating the base foam material with the thermoplastic substance. In the case of using an emulsion of the thermoplastic substance, a method for volatilizing the solvent after the impregnation is not particularly limited, and thus a method of blowing the hot air, or the like, can be adopted. Moreover, although the impregnation amount of the thermoplastic substance is not particularly limited, a amount of 0.01 to 0.1 g/cm³ is preferable.

Then, the base foam material impregnated with the thermoplastic substance is heated and compressed to a

predetermined thickness so as to be retained for a predetermined time. Then, it is cooled down to a room temperature while retaining the compressed state. The compression amount is preferably to the half of thickness
5 of the base foam material before the compression or less for obtaining the excellent fluid sealing, soundproofing, thermal insulation performances in a portion to be processed.

The series of the shape retention operation can
10 also be executed, for example, by heating and compressing the base foam material after the thermoplastic substance impregnation by a thermal press, and cooling the same in the compressed state. Moreover, it is also possible to be carried out by heating the base foam material after the
15 thermoplastic substance impregnation in an oven, compressing the same by a press immediately after being taken out from the oven, and cooling. For the compression, a weight can be placed instead of using the press. Moreover, for the continuous production, it is also
20 possible to use a calendar roll for heating and compressing the base foam material after the thermoplastic substance impregnation by a hot roll, and cooling down the same while being compressed by a cold roll. Furthermore, in the case of impregnating the base foam material with the
25 thermoplastic substance dissolved in a solvent as an emulsion, and heating the same for drying the solvent, it

can be compressed and cooled down by a cooling roll immediately after drying, utilizing the heat at the time of the drying operation. The shape retention operation is not limited thereto, but any method capable of heating and
5 compressing the base foam material after the thermoplastic substance impregnation, and cooling down the same in the compressed state can be adopted.

It is preferable that the heating temperature in the shaping step is in a range of 80 to 200°C, and the
10 cooling temperature is in a range of 25 to 80°C.

After the cooling operation, by releasing the pressure, a shape memory foam material according to the invention can be obtained. The shape memory foam material of the invention has a shape memory property capable of
15 retaining the compressed state in a room temperature, and releasing the compressed state by heating. Therefore, mechanisms for the shape retention property and the shape recovery property exist in the shape memory foam material of the invention. Although the shape memory foam material
20 of the invention is not limited by a specific theory, the inventors presume that the shape retention property and the shape recovery property are realized by the following mechanisms.

Since a force for recovering the thickness
25 functions on the base foam material by the elasticity in the case it is compressed, a shape retention force more

than the recovery force is necessary for realizing the shape retention property. In contrast, the thermoplastic substance is softened so as to have the rigidity lowered in the case it is heated, and in some cases, it becomes liquid so that it can be deformed with a small stress in this state. Moreover, by cooling and solidifying the same in the deformed state, it can be a hardened product with a high rigidity so that the deformed shape can be retained. Therefore, in the case the base foam material is impregnated with the thermoplastic substance, heated and cooled down in the compressed state, the base foam material tends to recover the thickness by its elastic recovery force, but the compressed shape is retained by the thermoplastic substance hardened product so as to realize the shape retention property.

The shape memory foam material with the shape retained in the compressed state has a shape retention force more than the shape recovery force of the base foam material. In the case the shape recovery force is more than the shape retention force, the shape recovery property is realized. Therefore, reduction of the shape retention force is an effective means. In the shape memory foam material in the invention, the shape retention force is reduced by heat application. As mentioned above, since the thermoplastic substance is softened by heating so as to be deformed by a small stress, the thermoplastic substance

hardened product is softened by heating so that the shape retention force is lowered. Thereby, the elastic recovery force of the base foam material exceeds the shape retention force. As a result, the shape recovery property is realized in the shape memory foam.

The above-mentioned is the mechanism of realization of the shape retention property and the shape recovery property of the shape memory foam of the invention.

For the heating operation for the shape recovery, for example, a method of pressing a hot plate heated to a predetermined temperature, a method of blowing hot air, or the like, can be adopted. The heating temperature thereof can be set optionally according to the thermoplastic substance melting point or glass transition point.

The shape memory foam material according to the invention can be used for the purpose of fluid sealing, soundproofing, and thermal insulation at a joint of a building, industrial machinery, and an automobile like the conventional materials. As mentioned above, a foam material is, in general, compressed and mounted in a portion to be processed, and fills the gap of the joint by the shape recovery by the elastic force of the foam material itself. However, in the case of the conventional foam materials, since they recover the original shape instantaneously in the case the pressure is released, they should be mounted in the portion to be processed while

keeping the state resisting to the recovery force in the compressed state, and thus the mounting operativity is extremely poor. By thinning the foam material, the mounting operativity can be improved, but since a gap is generated, the soundproofing and thermal insulation performances are insufficient. Moreover, the operativity can be improved to some extent by using a soft foam material for lowering the recovery force of the foam material in the compressed state; however, the effect is slight, and rather the fluid sealing performance is made poorer.

In contrast, since the shape memory foam material of the invention has the shape retained in the compressed state, it can be mounted to the portion to be processed extremely easily. Moreover, since the shape is recovered for filling the gap by heating after the mounting operation, the fluid sealing, soundproofing, and thermal insulation performances can be provided sufficiently. Furthermore, in the case it is used in a machine to have heat generation by the drive, such as the industrial machinery, the automobiles later described, or the like, since the foam material shape is recovered by the heat generated by the machine operation, in some cases the heat application operation can be eliminated.

25 Moreover, the invention provides a soundproof cover
for an automobile engine using the shape memory foam

material.

FIG. 1 is a perspective view showing a soundproof cover for an engine 10 used in a V-engine 20. The soundproof cover for an engine 10 has a foam material 12 as a soundproof material on the substantially entirety on the engine side surface (inner surface) of a cover main body 11 made of a metal or a resin. It is fixed by bolts (not shown) in fastening holes 15 provided in an intake manifold 13, an intake collector 14, or the like.

Since the engine 20 has a complicated shape, conventionally, the gap between the cover main body 11 and the engine is filled by mounting the foam material 12 in the engine 20 in the state compressed in the thickness direction thereof, and recovering the thickness by the elastic force of the foam material itself so as to improve the soundproof effect. However, since the foam material 12 recovers the instantaneously in the case the pressure is released, the soundproof cover for an engine 10 should be mounted on the engine 20 while keeping the foam material 12 in the compressed state, resisting to the recovery force thereof, and thus the mounting operativity is extremely poor.

By thinning the foam material 12, the mounting operativity can be improved, but since a gap is generated with respect to the engine 20, the soundproofing performance is insufficient. Moreover, the recovery force

from the compressed state can be reduced by using a soft foam material 12, however, the effect is slight, and rather it leads to deterioration of the strength of the foam material 12 so that problems arises in that the life is shortened, or the like.

Furthermore, the foam material can be shaped according to the shape of the engine 20. However, the foam material 12 should be prepared according to the type of the engine 20, and further, in the case it is mounted in a plurality of portions in the engine, the foam material 12 should be prepared for each mounting portion so as to lead to the production cost increase. Besides, since the foam material 12 is not contacted with the engine 20 with pressure, slight gap generation with respect to the engine 20 cannot be avoided, and thus it is problematic also in terms of the soundproofing performance.

Therefore, a shape memory foam material of the invention is used as the foam material 12. As shown in FIG. 2 (for facilitating understanding, only the engine 20 and a shape memory foam material 21 are shown), the shape memory foam material 21 is retained in the state compressed in the thickness direction thereof, and thus unlike the conventional foam material, it can be mounted on the engine 20 without the need of resisting to the recovery force of the foam material in the compressed state. In this state, as shown in the figure, a gap exists between the engine 20

and the shape memory foam material 21. Then, as shown in FIG. 3, in the case the shape memory foam material 21 in the compressed state is heated to a predetermined temperature, the shape memory foam material 21 expands in the thickness direction so as to fill the gap and provide the closely contacted state with respect to the engine 20. Thereby, by using the shape memory foam material of the invention, not only the mounting operation on the engine can be facilitated, but also the soundproof performance can be improved.

The heating method for the shape recovery is not particularly limited, and a method of pressing a hot plate heated to a predetermined temperature against the cover main body 11, a method of blowing hot air by a drier, or the like, can be adopted. Moreover, the temperature in bonnet can frequently be about 80°C by an idling drive of the engine in a room automobile. Some of the shape memory foam materials recover the shape at a temperature lower than the above-mentioned, for example, about 75°C. In this case, the idling drive of the engine 20 is sufficient without the need of the heating operation particularly so that the number of the mounting operations can be reduced.

Embodiments

Hereinafter, the invention will be explained in further details with reference to the embodiments, but the invention is not limited thereto.

(Embodiment 1)

5 A urethane foam having bulk density of 25 kg/cm³,
water absorption coefficient of 0.76 g/cm³, and a thickness
of 14.5 mm, and a shape of 50 mm × 50 mm in the
uncompressed state was impregnated with an emulsion of 50%
by weight concentration and containing an ethylene-vinyl
acetate-vinyl chloride copolymer having a glass transition
point of 50°C. After squeezing by a squeezing roller, it
was dried at 120°C for 20 minutes. After the drying
10 operation, it was compressed by a thermal press of 100°C
together with a spacer of 5 mm in thickness, and retained
for about 5 minutes in the state. Then, the thermal press
was cooled down to 25°C. After the cooling operation, the
shape retaining operation for releasing the pressure was
15 executed so as to produce a test piece.

(Embodiment 2)

In the same process as in the embodiment 1 except
that an emulsion of 25% by weight concentration of an
ethylene-vinyl acetate-vinyl chloride copolymer was used, a
20 test piece was produced.

(Embodiment 3)

In the same process as in the embodiment 1 except
that an emulsion of 50% by weight concentration and
containing an ethylene-vinyl acetate-acrylate copolymer
25 having a melting point of 72°C was used, a test piece was
produced.

(Embodiment 4)

5 The same urethane foam as in the embodiment 1 was impregnated with an emulsion of 50% by weight concentration and containing a styrene-acrylate copolymer having a glass transition point of 92°C. After squeezing by a squeezing roller, it was dried at 120°C for 20 minutes. After the drying operation, it was compressed by a 120°C thermal press together with a spacer of 5 mm in thickness, and retained for about 5 minutes in the state. Then, the thermal press was cooled down to 25°C. After the cooling operation, the pressure was released so as to produce a test piece.

(Embodiment 5)

15 The same urethane foam as in the embodiment 1 was impregnated with a 50% by weight concentration emulsion containing a polystyrene having a glass transition point of 100°C. After squeezing by a squeezing roller, it was dried at 120°C for 20 minutes. After the drying operation, it was compressed by a thermal press of 120°C together with a spacer of 5 mm in thickness, and retained for about 5 minutes in the state. Then, the thermal press was cooled down to 25°C. After the cooling operation, the pressure was released so as to produce a test piece.

(Comparative Example)

25 The same urethane foam as in the embodiment 1 was compressed by a thermal press of 100°C together with a

spacer of 5 mm in thickness, and retained for about 5 minutes in the state. Then, the thermal press was cooled down to 25°C. After the cooling operation, the pressure was released so as to produce a test piece.

5 The test pieces of the embodiments were obtained by impregnating a urethane foam having a water absorption coefficient of 0.2 g/cm³ or more, and a bulk density of 100 kg/m³ or less with a thermoplastic resin having a glass transition point of 120°C or less or melting point of 120°C
10 or less, heating and compressing, cooling down the same to a room temperature (25°C) while keeping the compressed state, and releasing the pressure after the cooling operation. In the embodiments 1, 2, the same thermoplastic resin was used, but the resin emulsion concentration and
15 the impregnation amount according thereto differ. Moreover, the embodiments, 1, 3, 4, 5 differ in terms of the thermoplastic resin composition. The comparative example provides a test piece of a urethane foam not impregnated with a thermoplastic substance.

20 For each of the test pieces, the thickness was measured at 25°C after the shape retaining operation. Further, a shape retaining test and a shape recovery test were executed. In the shape retaining test, the test piece was placed in a constant temperature vessel of 30°C, and
25 the thickness was measured after 24 hours, 72 hours, and 168 hours. Moreover, in the shape recovery test, 5 test

pieces were prepared so that each can be placed in a constant temperature vessel of 40°C, 60°C, 80°C, 100°C, and 120°C, and the thickness was measured after 5 minutes and 30 minutes. The physical property and the thickness after
5 the shape retaining operation of each test piece are shown in Tables 1 and 2. Results of the shape retaining test are shown in FIGS. 4 and 5, and results of the shape recovery test are shown in FIGS. 6 and 7.

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Although each test piece of the embodiments retained a thickness close to the spacer thickness of 5 mm, the test piece of the comparative example recovered the original thickness immediately after the shape retaining operation without the shape retention. Moreover, in the shape retention test, each test piece of the embodiments had a substantially constant thickness after a slight recovery of the thickness after passage of 24 hours so as to keep the substantially same thickness at the time of passage of 24 hours after passage of 168 hours. In contrast, the test piece of the comparative example recovered the original thickness at the beginning of the test so as to keep in the state as it is. Furthermore, in the shape recovery test, each test piece of the embodiments substantially recovered within 30 minutes in a temperature range between 60°C and 120°C, which is the glass transition point or the melting point of the thermoplastic resin used.

In contrast, the test piece of the comparative example already recovered the original thickness at the beginning of the test so that change by heating was not observed. From the results, it is apparent that the shape memory foam materials of the invention have good shape retention property and shape recovery property.

As heretofore explained, according to the invention,
25 a foam material having the excellent performances in fluid
sealing, soundproofing, and thermal insulation as well as

the excellent mounting operativity to a portion to be processed, to be obtained inexpensively without the need of special material or facility at the time of production, can be provided. Moreover, according to the invention, a soundproof cover for an automobile engine having the excellent soundproof property and mounting property can be provided.

1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808